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Original Research

Effects of Mobile Phone Radiation on Germination and Early Growth of Different Bean Species

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Abstract

Five species of beans were chosen to observe the effects of intermittent periods and doses of cell phone electromagnetic field radiation (EMR) on germination seeds. Beans were grown under the same environment and the EMR was different. The treatment included two intermittent periods (4 and 24 h) and three radiation intensities (high, low, and check). The frequency of EMR was 1805-1850 MHz. The mean power density was 0.4809 mW/cm^2 for high treatment and 1.455 mW/cm^2 for low treatment. The specific absorption rating (SAR) values were measured and expressed as units of W/kg for the five beans. The effects of EMR on the germination rates of seeds were inconsistent. Germination differed under EMR treatment for red bean, soybean, and Mologa bean but not mung and Hyacinth bean. The 24 h intermittent exposure had a significant effect on the height and fresh weight of mung beans. Results differed under high, low, and with check. The 4 h intermittent exposure did not significantly affect the height or fresh weight. Hyacinth and mologa beans showed similar results. Only 24 h intermittent exposure with high treatment had a significant effect on height and fresh weight. Under the same EMR and exposure times the received dose was the same. However, bean species had different germination.

Keywords: cell phone, electromagnetic field radiation, specific absorption rating, germination rate, beans

Introduction

Mobile phones have been developed as wireless communication devices and have exponentially increased in use because of their convenience. The primary mobile communication bands are 850 MHz and 1900 MHz in North, Central, and South America. Most providers have adopted 900 MHz and 1800 MHz in Europe and Asia. Many people are concerned about the effects of radiation energy on biological activity [1]. Electromagnetic waves at very high frequencies, such as X-rays, could damage human tissue. However, no significant effect of mobile phones and base stations that operate at the microwave range has been found on the human body or plants. The emitted energy is too low to damage chemical bonds, and many research results have been inconsistent. More studies are needed to explain the effect of radiation at low frequencies on living beings.

Experimental factors affecting biological systems are very difficult to control. Plants may be more appropriate than animals and human beings for studying the effects of radiation as they are more sensitive to their environment [2, 3]. However, besides radiation, several factors influence the growth of plants, such as day and night temperatures, light quantity, light quality, and fertilization. If the growing stage is long, pests and other diseases can affect experimental results.

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Many studies of the effects of radiation have led to conflicting conclusions, which may be explained by the difficulty in indentifying domain parameters. Time of radiation may be another factor affecting experimental results. Some studies have measured response after hours, days, or months. Davies [4] found that bioelectromagnetic results were rarely re-demonstrated.

Roux et al. [5] tested tomato plants exposed to 900 MHz radiation and found that the response at the organic and cellular levels was difficult to measure. Smith et al. [6] found that applying 60 MHz radiation during sprouting and early growth of *Raphanus sativus* affected plant performance and delayed germination. Flax plants exposed to radiation at larger frequencies followed by calcium deprivation showed meristem production [7]. Similar tests performed with weak environmental stresses followed by 2 days of calcium deprivation have also led to meristem production [8]. The seedlings did not show evidence of damage and the growing conditions of buds and shoots were normal.

To explain the effect of radiofrequency electromagnetic fields (RF-EMFs) on seed germination at the cellular level, *Alliums capa* L. seeds were exposed to 2 and 4 h EMFs of 400 and 900 MHz [9]. The results were different at the morphological and biochemical levels.

Cell phones are seldom utilized continuously. The effect of EMR radiation on users is intermittent. Most related studies have investigated the effects of electromagnetic field radiation or magnetic fields. In this study, five species of beans were chosen to observe the effects of the intermittent period and dose of cell phone EMR on germination and early growth of different bean species. The testing materials are grown in a growth chamber. The air temperature and relative humidity were controlled and circular fans were used to ensure a uniform environment. No light energy was required for seed germination, so the light factor was not considered. The root environment was kept moist and the required nutrition was provided by itself. The walls of the growth chamber were insulated well with metallic plates. The only source affecting seeding germination was EMR. No differences of growth factors between control and exposures plants could be ascribed. To avoid visual errors, statistical analysis was used to evaluate the significance of affecting factors.

Materials and Methods

Plant Material

Five species of bean seeds were purchased from a local market (Wufeng, Taichung, Taiwan): mung bean (*Vigna radiate* L.), red bean (*Vigna angularis*), Soybeans (*Glycine max* (L.) Merr.), hyacinth bean (*Lablab purpureus*), and mologa bean (*Vigna unguiculata* subsp. *cylindrica*). Seeds were carefully selected to ensure uniform size and shape. All seeds were imbibed in distilled water for 12 h, and then spread uniformly on moist filter paper in a 10 cm Petri disk. The number of seeds for each treatment was 60.

EMR Treatment

Cell phone electromagnetic radiation (EMR) exposure was executed in a growth chamber (100 cm×60 cm×50 cm). The walls of the chamber were completely covered with two layers of aluminum sheets 3 mm thick to ensure that the experimental environment was free from outside interference. The inner layer was adhered with foam materials to reduce the effects of resonant cavity. The EMR pulse signal was transmitted from the outside environment to the chamber by a Band selective repeater (TG-1800Dcs, Coiler International, Hsichih, Taiwan). The frequency range was from 1805 to 1850 MHz. The gain was greater than 60 dB. The EMR signal was transmitted into the left side of the chamber and the field exposure strength was then classified in high and low regions. The diagram of the experimental set-up is shown in Fig. 1. The power flux density was measured with the use of an RF power density meter (CA 43 fieldmeter, Chauvin Arnoux, Normandy, France). The mean power density (Pd) values for high treatment were 0.4809 mW/cm^2 (ranging from 0.405 to 0.572 mW/cm^2) and for low treatment was 0.1455 mW/cm^2 (ranging from 0.1023-0.1648 mW/cm^2). The contours of these measurement values were plotted by using Sigma plot v10.0 (SPSS Inc., Chicago, IL.) and shown as Fig. 2.

There were two growth chambers used in this study. The first was used to provide the EMR signal with high and low treatments. The second was only used for the check test.

Four temperature meters (TR-TMPaA4 transmitter, Yalab co., Taipei, Taiwan) were used to compare the temperature difference. Three meters were installed to measure the temperatures of three positions under high treatment, low treatment, and in the center (Fig. 1). One meter was used to measure the temperature under check. However, no significant difference could be found among these measurements.

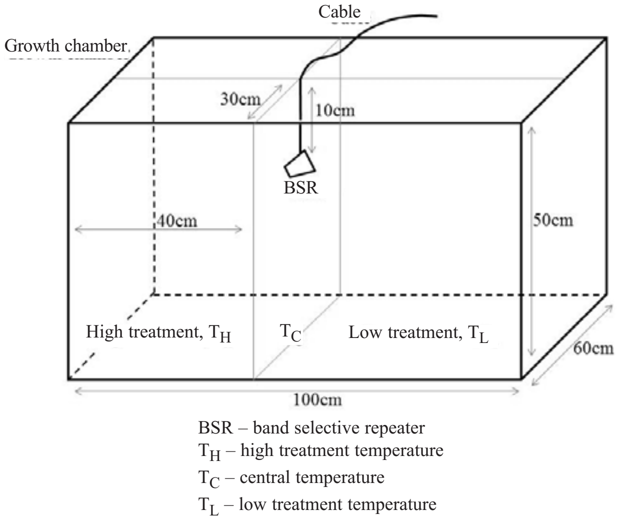


Fig. 1. Design of the experimental set-up for exposure to cell phone.

Table 1. The mean and range of specific absorption rating (SAR) values for five beans.

Varieties	High treatment (mW/kg)			Low treatment (mW/kg)		
	Mean	Max	Min	Mean	Max	Min
Mung Bean	7.14208×10^{-2}	6.01485×10^{-2}	8.49505×10^{-2}	2.16089×10^{-2}	1.519307×10^{-2}	8.49505×10^{-2}
Red Bean	1.07828×10^{-1}	9.08092×10^{-2}	1.28254×10^{-1}	3.26240×10^{-2}	2.29378×10^{-2}	3.69516×10^{-2}
Soybean	1.20743×10^{-1}	1.01686×10^{-1}	1.43616×10^{-1}	3.65317×10^{-2}	2.56852×10^{-2}	4.13775×10^{-2}
Hyacinthm Bean	2.12675×10^{-1}	1.79109×10^{-1}	2.52964×10^{-1}	6.43465×10^{-2}	4.52416×10^{-2}	7.28818×10^{-2}
Mologa bean	1.94483×10^{-1}	1.10284×10^{-1}	1.55759×10^{-1}	3.96205×10^{-2}	2.78569×10^{-2}	4.48760×10^{-2}

The intermittent period was 24/24 h and 4/4 h and the three treatments were high, low, and check. For the 24/24 h intermittent period, these seeds were exposed under radiation for 24 h and cell phone power was turned off for 24 h. Then exposure under radiation was executed again.

The specific absorption rating (SAR) value was adopted as the safety standard for mobile phones. The SAR measurement can be detected under the thermal effect [10, 11]. In this study, the effects of EMR on the temperatures of three treatments were not significantly different. This could be due to air circulation in the growth chamber and water evaporation from filter paper. So the SAR value could not be measured with thermal technique in this study. Many methods of SAR measurement were introduced [12]. The Differentia-Power technique was adopted in this study. The power of input, output, and reflection was detected, and the power adsorbed (PE) by the empty exposure device was computed. Then the sample (beans) was placed in the exposure device, and the power adsorbed by sample and exposure device was determined (PS) using the same method. The difference between PS and PE is referred to as the PD value. The mass of sample (beans) was measured using an electrical balance (Sartorius TE3102S Analytical balance, Sartorius AG, Goettingen, Germany). The accuracy of this balance was within 0.01g. The SAR value was calculated by dividing the PD values and the mass of samples.

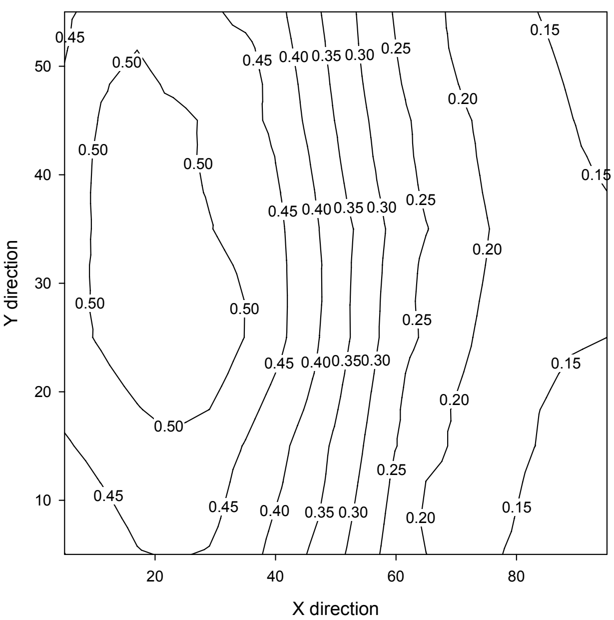


Fig. 2. Distribution of the power density (mw/cm^2) of EMR signal in growth chamber.

The calculated SAR values for five beans are listed in Table 1. The contours of SAR values for different beans are shown in Fig. 3.

Growth Studies

All seeds were placed in 10 cm diameter Petri dish in the different positions of a growth chamber. Moist sterile filter paper was placed at the bottom of the dish to maintain moisture. Dishes were watered regularly. The microclimate of the chamber was kept at 28ºC during the day temperature and 23ºC at night. The relative humidity was maintained at 80±5%. The intermittent exposure period of EMR was controlled by a timer.

The experiments were executed with a completely randomized design: six replications for each treatment and 10 seeds were placed in a Petri dish. A total of 60 seeds were used to observe the effect of EMR exposure.

Measurement of Growing Parameters

The germination rate was calculated and shoot height from the base was measured for each day. As the growth condition reached the final stage, plants were harvested and fresh weights were measured. The required growth days differed according to seed characteristics.

Statistical Analysis

Data are presented as the mean value and standard error.

The Effects of Radiation Intensities on Fresh Weight and Shoot Height

The effects of radiation intensities on fresh weight and shoot height were analyzed by one-way analysis of variance (ANOVA) followed by Tukey's post-hoc least significant difference (LSD) testing. $P < 0.05$ was considered statistically significant.

The Effect of Radiation Intensities on the Germination Rate

The germination rate was analyzed with a germination model based on the following equation:

$$Y = \frac{Y_{\max}}{1+\exp(-B(t-A))} \quad (1)$$

...where Y is germination; t is time; and Y_{max}, A, and B are constants.

This equation is based on physiological theory (13). The three parameters each have biological meaning: final germination percentage Y_{max}, curve inflection point A, and germination rate B (day^{-1}).

Constants were estimated by nonlinear regression analysis with the statistical software Sigma plot v10.0 (SPSS Inc., Chicago. IL).

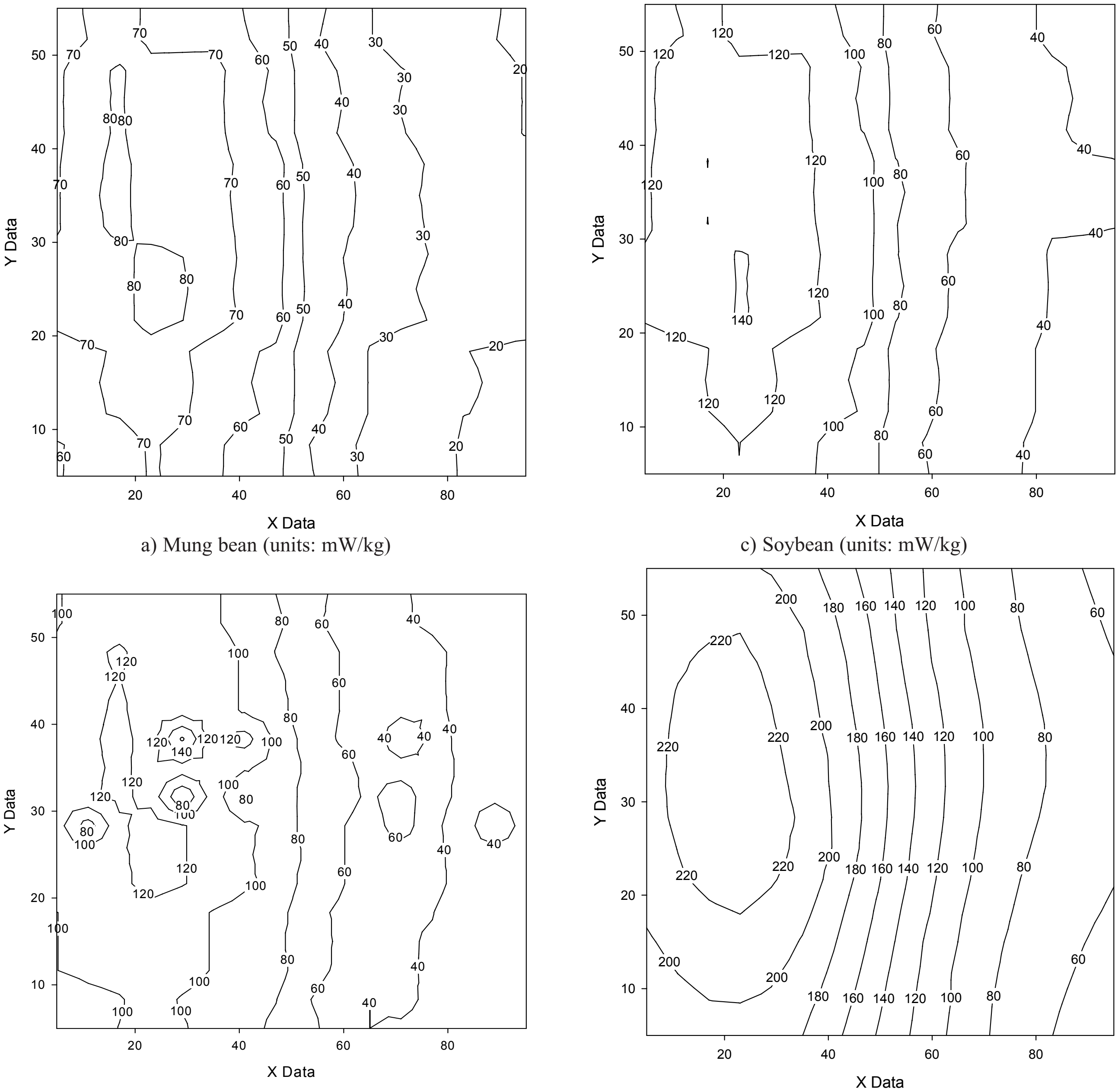
To determine significant differences among the germination data of different treatment, an F-statistical technique was used, which can be used for linear models or nonlinear models [14]. The F-statistic significance was checked at p<0.05. The detailed procedure is as follows.

Each dataset was fit with the logistical equation and the sum of square errors was calculated for each model (SS_1, SS_2, SS_3) of the three treatments. Data were pooled and fit with the logistical equation to find the sum of square errors (SS_t). The F-statistic was calculated as:

$$F_1 = \frac{(SS_t - SS_1 - SS_2 - SS_3)/(df_c - df_1 - df_2 - df_3)}{(SS_1 + SS_2 + SS_3)/(df_1 + df_2 + df_3)} \quad (2)$$

...where df_i is the degree of freedom of i term.

The decision was: If $F_1 < F$ (P;v_1; v_2), all sets of data are different.



a) Mung bean (units: mW/kg)

c) Soybean (units: mW/kg)

b) Red bean (units: mW/kg)

d) Hyacinth bean (units: mW/kg)

Fig. 3. Distribution of the specific absorption rating (SAR) values for beans.

Results and Discussions

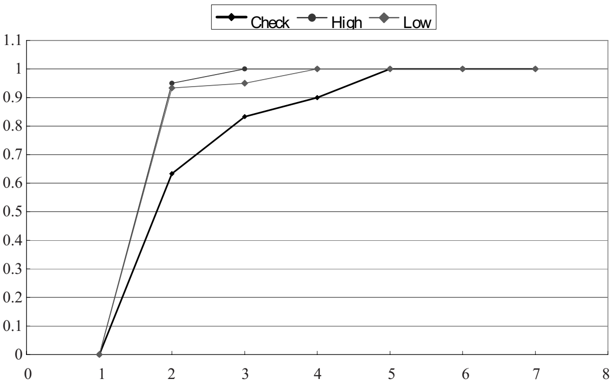
Effect of EMR on Seed Germination of Mung Bean

Germination of mung bean with three EMR treatments did not differ for 24 h (Fig. 4a) or 4 h (Fig. 4b) intermittent exposure. The effects of EMR for two exposure periods on the height of the mung bean are presented (Fig. 5). From the one-way ANOVA test, the height under 24 h intermittent exposure significantly differentiated between the three treatments ($F(2, 236) = 4.67$, $P < 0.001$). Tukey's post-hoc LSD analysis revealed that height with high exposure was significantly lower than that under the other two treatments. However, 4 h intermittent exposure and all treatments had no effect on the height of the mung bean.

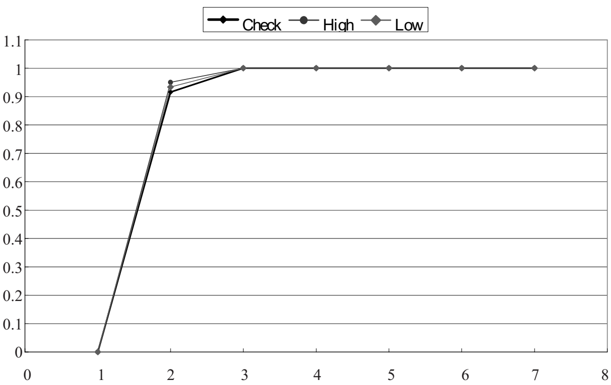
The significant difference was found between the treatment with check and high treatments with 24 h intermittent, with no difference between high and low treatment. With 4 h intermittent exposure, fresh weight did not differ under EMR exposure (Fig. 6).

Effects of EMR on Red Bean

With 24 h intermittent exposure, the germination rate was reduced in general with EMR. However, with 4 h intermittent exposure, EMR did not affect germination rate after 4 days (Fig. 7).

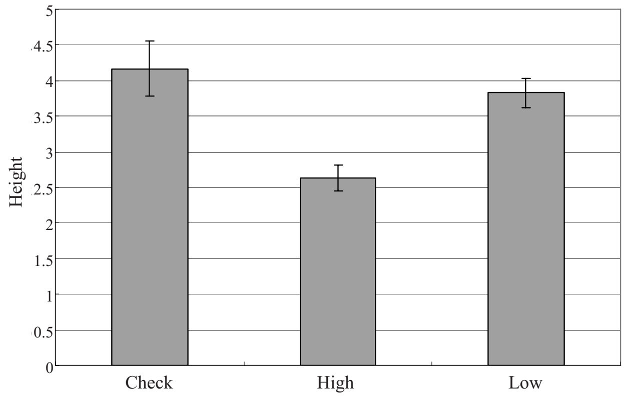


a) 24 h intermittent exposure

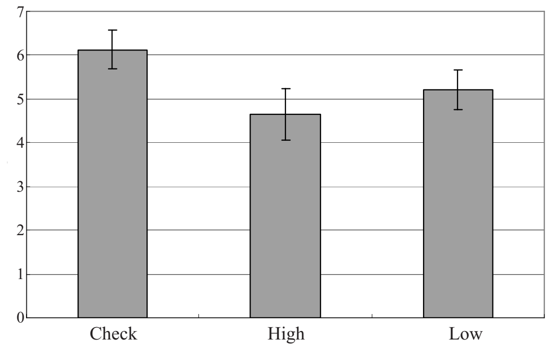


b) 4 h intermittent exposure

Fig. 4. Effects of electromagnetic field radiation (EMR) with two intermittent exposure times on mung bean germination.



a) 24-h intermittent exposure



b) 4-h intermittent exposure

Fig. 5. Effects of EMR with two exposure times on mung bean height.

The estimated parameters of germination rate equations are listed in Table 2.

In the logistic equation, Y_{max} is the germination limitation and the B value represents the increasing rates of germination. From the estimated parameters of the equation, for 24 h exposure, according to regression analysis, the maximal germinations for the three treatments were 1.5253, 0.7802, and 0.8263, where EMR exposure decreased the germination rate. The maximal germination rates were similar for the three EMR exposures, that is 0.8829, 0.898, and 0.8819, respectively.

For 4 h exposure, the germination rates for low and high treatment were similar, 1.7978 and 1.8176, respectively, with higher rates under check during the first 3 days.

Height and fresh weight did not differ under the two intermittent exposure times or three EMR treatments (Figs. 8 and 9, respectively).

Effects of EMR on Soybeans

From the parameters of the equations (Table 2), the exposure treatment affected germination rate and maximum germination. For 24 h exposure, the germination rates were similar with those under low and high EMR treatment and lower than with check (Fig. 10).

The estimated parameters of the germination equations of 4 h intermittent are listed in Table 2. The effects of the three treatments on germination showed significant difference.

Table 2. Estimated parameters for the germination of five beans species.

Bean species	Intermittent hours	Experiment design	Estimated values of constants		
			Y_{max}	B	A
Red bean	24	N[1]	0.8829	-1.5253	2.2983
		L[2]	0.8985	-0.7802	3.4384
		H[3]	0.8819	-0.8263	2.9857
	4	N	0.8468	-1.7535	2.1287
		L	0.8334	-1.7978	2.4552
		H	0.8421	-1.8176	2.5581
Soybeans	24	N	0.8171	-1.3785	2.7174
		L	0.7454	-0.9288	3.5560
		H	0.6401	-1.2149	3.1601
	4	N	0.7903	-1.7135	2.5491
		L	0.6371	-1.7301	2.7747
		H	0.7302	-0.7782	3.9223
Mologa bean	24	N	0.7680	-1.0753	3.4022
		L	0.7351	-1.0762	3.5537
		H	0.7356	-0.8551	3.9921

N – Check, L – Low treatment, H – High treatment, Y_{max}, *B*, and *A* are constants

For 4 hr exposure, germination was the highest with no EMR treatment and the lowest with high treatment.

Height and fresh weight of soybeans did not differ (data not shown).

Effect of EMR on Hyacinth Bean

Germination did not differ according to EMR exposure time or treatment (Fig. 11). Height and fresh weight were significantly reduced with high EMR treatment but not with low treatment (data not shown). The results of the ANOVA test revealed significant differences among the three treatments. Tukey's post-hoc LSD analysis indicated that height and weight varied significantly between high treatment and with check. No difference could be found between low treatment and with check.

Effects of EMR on Mologa Bean

The estimated parameters of the germination equations for the three treatments are listed in Table 2.

With 24 h intermittent EMR exposure, germination showed no difference under low treatment and with check. However, these two treatments varied significantly in comparison with the results under high treatment (Fig. 12). With 4 h intermittent exposure, germination did not differ among the three treatments (data not shown).

The ANOVA results revealed significant differences among the three treatments. Tukey's post-hoc LSD analysis indicated that the height and weight of Mologa beans differed under high treatment and with check but not under low treatment (data not shown).

The effect of EMR on the germination rate of seeds was inconsistent (Table 3). Seed germination differed according to EMR treatment for red bean, soybean, and mologa bean but not for mung and Hyacinth bean. The 24 h intermittent exposure had a significant effect on the height and fresh weight of mung beans. Results differed between high treatment and low treatment and with check. The 4 h intermittent exposure did not significantly affect height or fresh weight. Hyacinth and mologa beans showed similar results. Only 24 h intermittent exposure with high treatment had a significant effect on height and fresh weight. Even with the same EMR time and dose, the effects on germination differed among beans.

Discussion

Plants serve as a better model than animals for evaluating of the effect of EMR on living systems. They are immobile and sensitive to the environment. However, many envi-

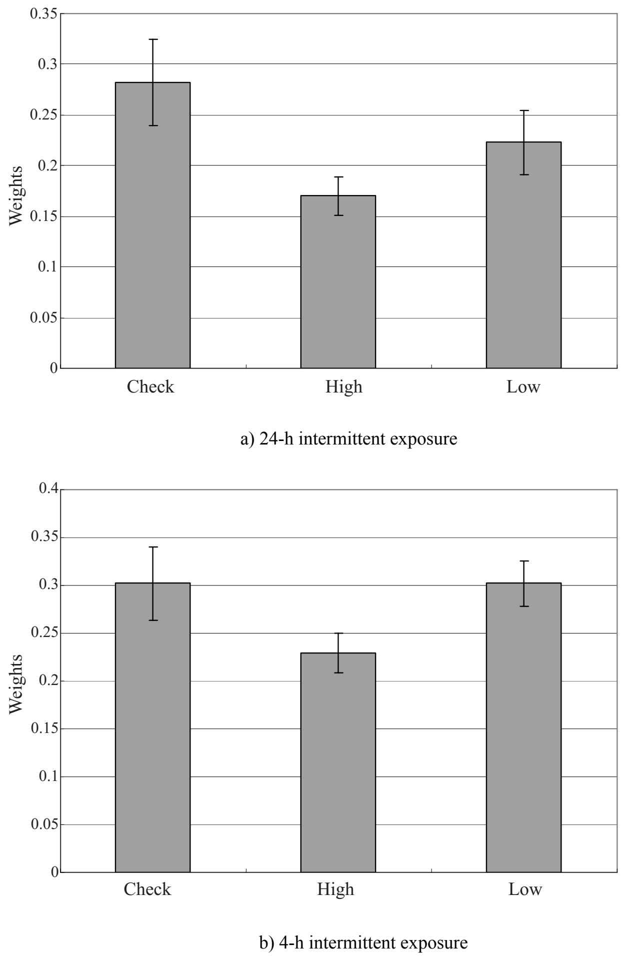


Fig. 6. Effects of EMR with two exposure times on the fresh weight of mung bean.

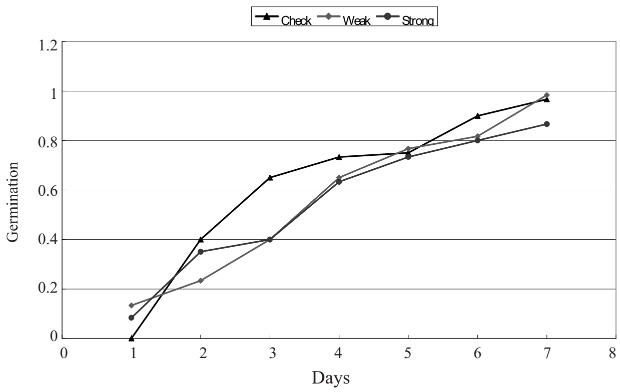
Table 3. Comparison of effect of electromagnetic field radiations (EMR) on the germination of five species of beans.

		Mung bean	Red bean	Soybeans	Hyaciuth bean	Mologa bean
Family		*Fabaceae*	*Faboideae*	*Fabaceae*	*Fabaceae*	*Papilionaceae*
Genus		*Vigna*	*Vigna*	*Clycine*	*Lablab*	*Vigna*
Index	Intermittent exposure					
Germination	24 h	NS	C > H ≅ L	C > L ≅ H	NS	C > H ≅ L
	4 h	NS	C > H >L (at the first 3 day)	C > L >H	NS	NS
Height	24 h	C > H ≅ L	NS	NS	C ≅ L > H	C ≅ L >H
	4 h	NS	NS	NS	NS	NS
Weight	24 h	C > H ≅ L	NS	NS	C ≅ L > H	NS
	4 h	NS	NS	NS	NS	NS

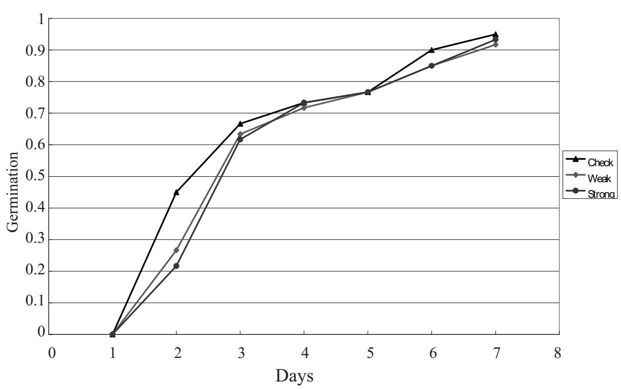
C – Check, L – Low treatment, H – High treatment, ≅ – No significant difference of two treatments, NS – No significant difference of three treatments

ronmental factors can affect the observation of the effects of EMR. Aerial environmental factors such as temperature, humidity and light intensity have significant effects on growth characteristics. The root environment of water content, pH, and electrical conductivity (EC) value also affects growth. Other uncontrollable variations are pests and disease infection. In this study, bean seeds were selected as testing materials and grown in a growth chamber. The only source affecting seeding germination was EMR. This methodology is simple and effective. No differences of growth factors were ascribed between control and exposure. The significance of affecting factors was evaluated by statistical analysis.

Previous results have shown inconsistent results. Sharma et al. [15] observed that cell phone EMR (900 MHz

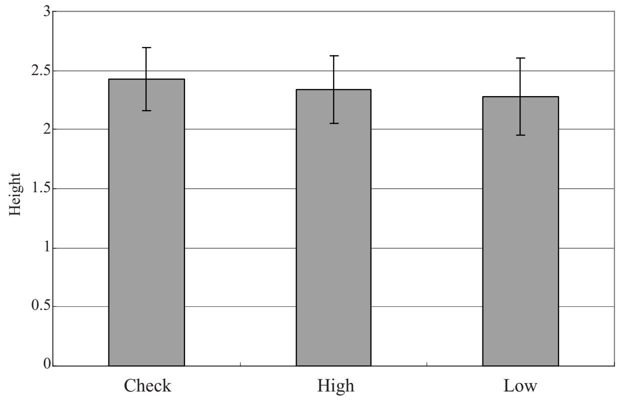


a) 24-h intermittent exposure

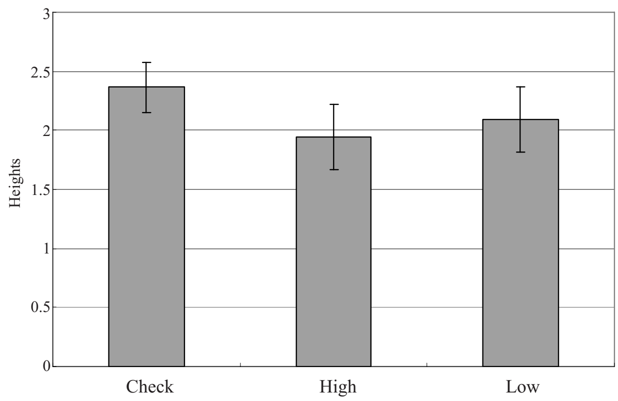


b) 4-h intermittent exposure

Fig. 7. Effects of EMR with two intermittent exposure times on germination of red bean.



a) 24-h intermittent exposure



b) 4-h intermittent exposure

Fig. 8. Effects of EMR with two exposure times on height of red bean.

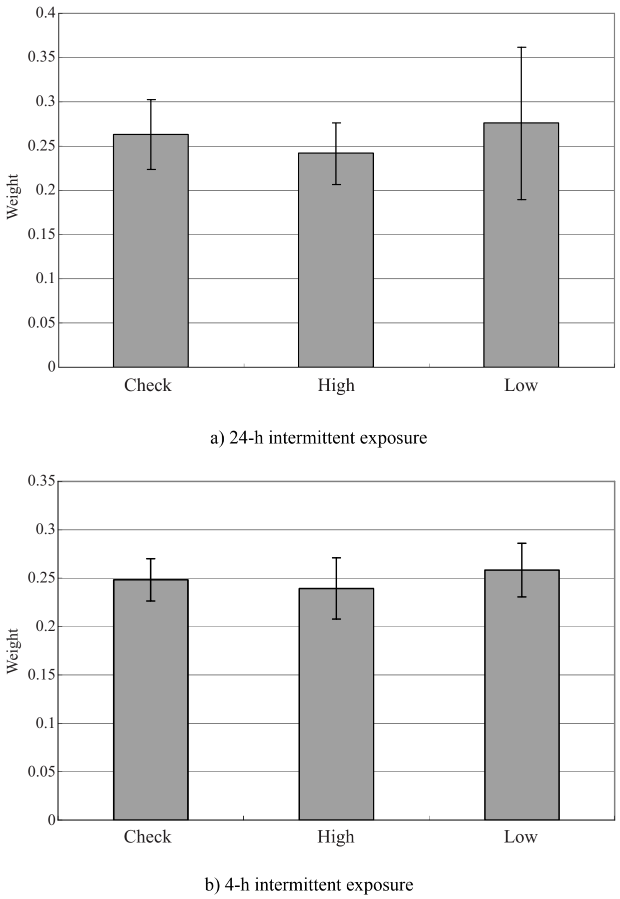


Fig. 9. Effects of EMR with two exposure times on fresh weight of red bean.

and 8.55µW/cm^2) significantly reduced mung bean germination. The longer the exposure time, the greater the reduction. Afzal and Mansoor [16] analyzed the effect of mobile phone radiation (900 MHz) on morphological parameters of mung bean and wheat seedlings. EMR did not reduce the germination of mung bean. However, exposure slightly decreased the germination of wheat seedlings. Tkalec et al. [9] studied the effects of EMF (400 and 900 MHz, 4 hr, 4 field strengths) on seed germination of *Allium cepa* L. and found no significant differences between check and others treatments.

The findings of Sharma et al. [15] indicted that the EMR inhibite the radicle and plumule lengths of mung bean. Afzal and Mansoor [16] found the length and fresh weight of mung bean, and wheat seedlings all decrease with EMR treatment. Tkalec et al. [9] found no significant differences in root length of *Allium Cepa* L. with check and five other treatments. Akbal et al. [17] indicated that the root growth of Lens culinaris Medik decreased with EMF treatment. The above results are inconsistent with the results of this study (Table 3).

The main problem in the study of the effect of cell phone EMR is that the physiology and mechanisms are poorly understood. The possible effects are still unclear. Previous results are contradictory. Davies [4] explained the different response of EMR with the growth of three plant species. The similar response of mustard and radish occurred because the species are taxonomically close and belong to the same family (*Brassicaceae*). In our study, inconsistent results were found for five species of beans. Mung, red, and mologa beans are in the same genus of *Vigna*. The effects of growth characteristics due to EMR exposure are inconsistent for these beans. The results for red bean and soybean are similar. However, both species belong to a different genus. Red beans belong to *Vigna* genus and Soybeans belong to *Clycine*. The effects of EMR exposure on germination performance could not be explained by their biological classifications.

Sharma et al. [15] evaluated oxidative stress according to four indices. Cell phone EMR induced oxidative stress in mung bean roots. The authors concluded that the reduction in germination and root growth of mung bean were due to oxidative stress. In the study by Tkalec et al. [9], mitotic indexes such as chromosome stickiness and vagrants were significantly increased by exposure to EMR. However, germination rate and root length were not altered. Afzal and Mansoor [16] found that EMF radiation damaged the cell membrane by evaluating malondialdehyde content and antioxidant enzyme levels. However, EMR was unable to reduce the germination of mung bean and only slightly decreased that for wheat seedlings. Akbal et al. [17] observed the effect of mobile phone EMR on Lens culinaris Medik. Germination was not affected, but root length was decreased and chromosome aberrations were negligible.

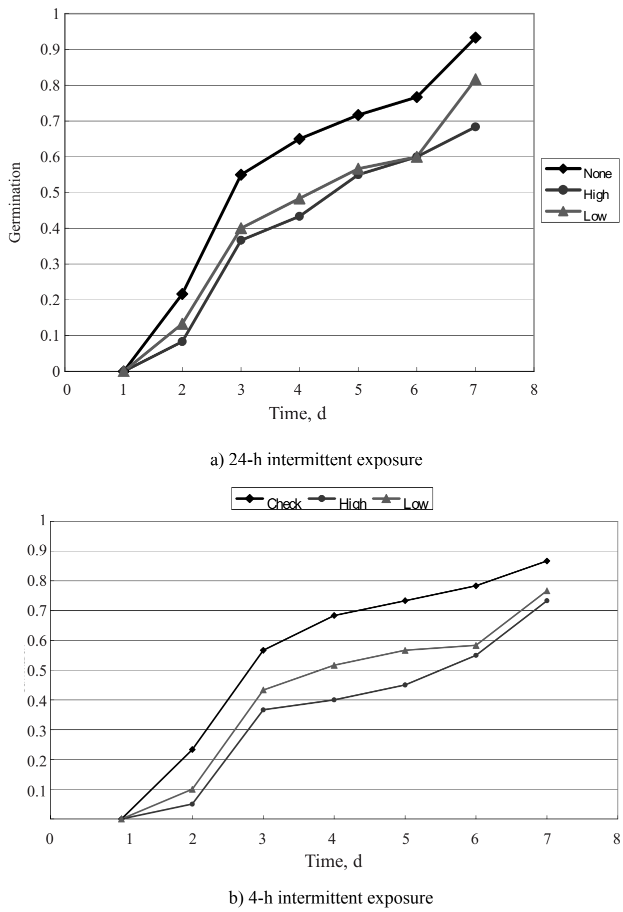


Fig. 10. Effects of EMR with two intermittent exposure times on germination of soybeans.

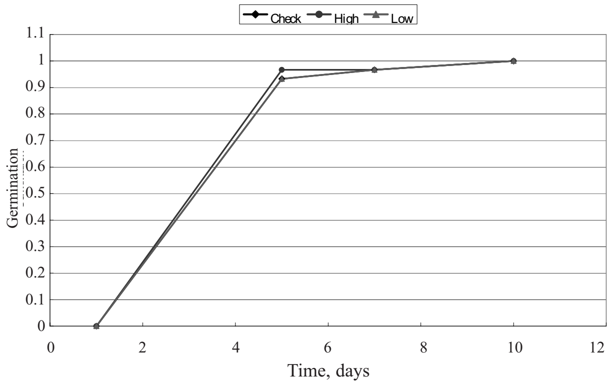


Fig. 11. Effects of EMR with 24 h intermittent exposure times on germination of Hyacinth bean.

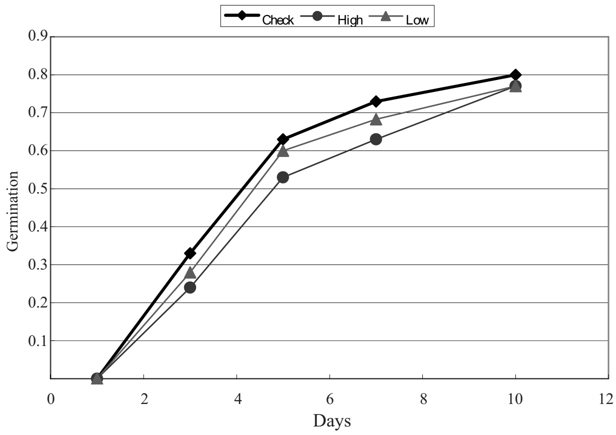


Fig. 12. Effects of EMR with 24 h intermittent exposure times on germination of mologa bean.

Thus, findings related to the effects of cell phone EMR on morphological and biochemical reactions in beans in the literature are still inconsistent. More detailed experiments are needed. Singh et al. [18] observed the effect of 900 MHz cell phone electromagnetic field radiation (EMFr) on the biochemical mechanism of root formation in mung bean hypocotyls. The EMFr-induced oxidative damage was confirmed by the up regulation in the activities of antioxidant enzymes.

The effects of magnetic field treatment on germination of plants have been reported in many studies. Reina and Pascual [19, 20] proposed and validated a model to express the relationship between the water uptake mechanism and a stationary magnetic field. The magnetic field interacts with the ionic current in the cell membrane, and then changes the osmotic pressure of the cell, so the water adsorption mechanism is enhanced. Smith et al. [21, 22] reported that low frequency electromagnetic fields (EMFs) could enhance the motility of diatoms and explained by increasing the transportation of calcium ions across the cell membrane due to EMF exposure. However, Clarkson et al. [23] tested the diatom motility in three strains of A. coffeaeformis and showed that the exposure of EMFs did not cause significant increase in diatom motility. These experiment results show the conflicting data and offer no convincing hypothesis. Smith et al. [6] reported that different frequencies also influenced the effect of a magnetic field. With different experimental setups, results were inconsistent. Aleman et al. [24] studied the effect of the electromagnetic fields (EMRs) on growth parameters of coffee plantlets. Their results showed that electromagnetic fields could increase growth activity and improvement of productivity.

After testing the effects of low-frequency magnetic fields on the germination of Durum wheat, Muszynski et al. [25] concluded that the responses of plants vary within the same species and treated them with the same magnetic fields. Experiments and theoretical works still could not obtain a similar conclusion. Yano et al. [26] observed that a 60 Hz magmatic field did not affect the CO_2 uptake rate and only slightly affected the growth of radish seedlings. Inconsistent biochemical and morphological results were also found for magnetic fields.

The experimental design of the study of the effect of EMR on the germination and growth index of seeds or plants usually focuses on EMF radiation and exposure time. Morphological indexes are plotted against time. Inconsistent results have been presented in the literature. The integral of temperature or light intensity is an important index to quantify the effect of environmental factors on greenhouse plants. The integration intensity of UV-B or thermal energy is a reasonable index for evaluating the viability of microorganisms on the sterilization process. In our study, the integral of EMR radiation and exposure time was the same. However, the effect on germination performance was significantly different.

Many studies have investigated the effect of radiation on cells or small animals with dosimetry in SAR values. However, the information related to plants and radiation expressed with dosimetry in SAR values is limited. More studies are needed to explain the effects of this type of radiation on seeds or plants.

Conclusions

Cell phones are utilized intermittently. The effects of the intermittent period and dose of cell phone electromagnetic field radiation (EMR) on germination seeds of five species of beans were observed. The testing materials are grown in a growth chamber and maintained with uniform air temperature and relative humidity. The only source affecting seeding germination was EMR. No differences of growth factors between control and exposures plants could be ascribed.

The results from this study indicated that effects of EMR on the germination rates of seeds were inconsistent. Germination was differed under EMR treatment for red bean, soybean, and mologa bean, but not mung and Hyacinth bean. The 24 h intermittent exposure had a significant effect on height and fresh weight of mung beans. Results differed under high, low, and with check. The 4 h intermittent exposure did not significantly affect the height or fresh weight. Hyacinth and mologa beans showed similar results. Only 24 h intermittent exposure with high treatment had a significant effect on height and fresh weight. Bean species had different germination under the same EMR and exposure time.

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